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Nonlinear association between soil lead and blood lead of children in metropolitan New Orleans, Louisiana: 2000–2005 ☆

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Abstract

Metropolitan New Orleans is unique because it has a universal blood lead (BL) screening dataset ($n=55{,}551$) from 2000–2005 spatially coupled with a soil lead (SL) dataset ($n=5467$) completed in 2000. We evaluated empirical associations between measurements of SL and BL exposure responses of children in New Orleans by stratifying the databases by Census Tracts and statistically analyzing them with permutation methods. A consistent curvilinear association occurred annually between SL and BL with robust significance (P-values $<10^{-23}$). The mathematical model of the pooled BL datasets for 2000–2005 is: $BL=2.038+0.172\times(SL)^{0.5}$ (agreement ($\mathfrak{R}$) of 0.534, an r^2 of 0.528, and a P-value of 1.0×10^{-211}) indicating that chance alone cannot explain the association. Below 100 mg/kg SL children's BL exposure response is steep (1.4 μg/dL per 100 mg/kg), while above 300 mg/kg SL the BL exposure response is gradual (0.32 μg/dL per 100 mg/kg). In 1995, the BL prevalence was 37% ≥ 10 μg/dL for the most vulnerable poor and predominantly African-American children. In the era of universal screening the prevalence of elevated BL is 11.8% ≥ 10 μg/dL for the general population of children. The SL map describes community variations of potential BL exposure. If health effects occur at BL ≥ 2 μg/dL, then 93.5% of the children in New Orleans are at risk. These results reinforce the proposal that prevention of childhood Pb exposure must include SL remediation as demonstrated by a New Orleans pilot project and a proactive Norwegian government program.

Keywords: Childhood lead exposure; Urban soil lead remediation; Health disparity; Environmental justice

1. Introduction

Previous assessments of the association between lead-contaminated soil and lead exposure have found widely varying relationships between soil lead concentrations (SL) and children's exposure as measured by blood lead (BL) (Reagan and Silbergeld, 1989; Xintaras, 1992). This study describes the empirical association of SL measurements paired with BL exposure responses of

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children living in residential communities of metropolitan New Orleans.

For perspective on SL, New Orleans is located on the Delta of the Mississippi River. The sediments from the Mississippi River are the parent materials of the alluvial soils of metropolitan New Orleans, and currently contain only trace amounts of lead (Pb) (median = 5 mg/kg) (Mielke et al., 2000). Despite the clean quality of the parent soils, the city of New Orleans now has ten census tracts (U.S. Census Bureau enumeration districts) with a median SL of ≥1000 mg/kg (Mielke et al., 2006a). Urban soils integrate all dust sources of Pb, including deteriorated lead-based paint (or its haphazard removal by power sanding, sand blasting, etc.), leaded gasoline emissions, and incinerator or industrial Pb emissions that have accumulated in the environment (Mielke, 1999, 2005). Soils then are both a sink and a source of Pb dust.

In metropolitan New Orleans, two SL surveys have been conducted (Mielke et al., 2005b). The first survey (Survey I) was completed in 1991 and was the basis for the first evaluation of the association between SL and BL (Mielke et al., 1997). The BL data were obtained from the Louisiana Office of Public Health in 1995. The exposure responses of BL to both age of housing (HA) and SL were evaluated (Mielke et al., 1997). In that study the *P*-value of the association between BL and HA (10^{-12}) was 12 orders of magnitude larger than the *P*-value between SL and BL (10^{-24}) (Mielke et al., 1997). This fact focused our attention on SL as a major factor in children's Pb exposure response as measured by BL. Detailed evaluation of the association between SL and BL of New Orleans children more clearly demonstrated the nonlinear association between SL and BL and the larger implications to society of the observed relationship (Mielke et al., 1999). The mathematical model of the SL and BL relationship was: $BL = 3.06 + 0.33\ (SL)^{0.5}$ (correlation coefficient = 0.69 between modeled BL and observed BL and $P = 3.5 \times 10^{-22}$) (Mielke et al., 1999). A similar association between SL and BL was found by Johnson and Bretsch (2002) in their study of Syracuse, NY.

The purpose of this study is to review the relationship between SL and BL using two new databases completed since the year 2000. The SL data for this study is derived from Survey II of New Orleans completed in 2000 (Mielke, 2002; Mielke et al., 2002, 2005b). In 2000, the Louisiana Department of Health began conducting universal BL screening of children living in metropolitan New Orleans. The present study describes and evaluates the empirical associations between Survey II SL measurements and childhood BL for the years 2000–2005 within residential communities of metropolitan New Orleans. Also, the findings from 2000–2005 were compared with those from 1995.

2. Materials and methods

Two datasets, SL and BL, were stratified by census tracts and assembled for this study.

2.1. Survey II soil lead (SL) data

The SL dataset was assembled from samples collected on the top 2.5 cm of the soil surface within residential neighborhoods of metropolitan New Orleans (Mielke et al., 2005b). Wherever possible, 19 samples per census tract were collected as described previously (Mielke et al., 2005a,b). The soil samples were stratified by 1990 Census Tracts ($n = 286$). Sampling was conducted by using U.S. Census Bureau maps as a guide (U.S. Census Tracts and Block Number Areas, 1993). Overall, Survey II included 5467 surface samples collected from 286 census tracts (Mielke et al., 2005b).

The extraction is based on room temperature leachate methods using 1 M nitric acid (HNO_3), a scheme that correlates well with total methods (Mielke et al., 1983; U.S. EPA, 1996). The method has the advantage of more closely resembling physiologic conditions compared with extraction methods based on the use of boiling and concentrated HNO_3. The extraction protocol requires mixing 0.4 g of dry and sieved (#10 USGS—2 mm) soils with 1 M HNO_3 and agitated at slow speed on an Eberbach shaker for 2 hours at room temperature (~22 °C). The extract is then centrifuged (10 min at 1600 ×*g*) and filtered using Fisherbrand P4 paper. The extract is stored in 20 ml polypropylene scintillation vials until analyzed. A Spectro Analytical Instruments CIROS CCD Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES) is used to analyze the metals in each sample. The ICP-AES is calibrated with NIST traceable standards, and a laboratory reference, at a rate of 1 per 15 samples, is analyzed during each run. Internal laboratory references included one low SL sample from New Orleans City Park and one high SL sample from the junction of Elysian Fields and Interstate 10 in the inner city of New Orleans. Duplicate extractions are included for every 15 samples. The final SL database is the median result of all samples collected in each census tract of metropolitan New Orleans (Mielke et al., 2005b).

2.2. 2000–2005 blood lead (BL) data

The BL dataset of children less than 6 years old was organized by the Section of Environmental